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Reflecting and Looking to the Future: What Is the Research Agenda for Theory in Health Informatics?

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Abstract. In this chapter, we reflect on the aim and objectives of the textbook and address known gaps in our theory coverage. We reinforce the importance of theory in health informatics and review the varying disciplinary origins of the theories considered in the book. We discuss the question of what makes a good theory and how to know which one is relevant for a given study. We recognize the limitations of the body of theory that we have presented and suggest what might be regarded as "native" theory that is original to health informatics. Finally, we propose topics to form a research agenda for theory in health informatics.

Keywords. Health informatics, Theory, Epistemology, Research

1. Introduction

We wanted this book to provide a scientific knowledge base to progress the agenda of evidence-based health informatics [4] by emphasising theory-informed work which sets out to 'enrich our understanding of this complex field' [5]. The first hurdle we confronted was that the definition of 'theory' within our field was ambiguous and needed to be broadened and made flexible so as to be "abstract enough to permit generalization, but concrete enough to permit testing". As a consequence, when predictive theories were not available, frameworks including (also non-causal) associations between concepts were selected. We have included fifteen different theories and frameworks in the book: five from information science and technology, nine from the social and psychological sciences and one ambitious framework that aims to integrate several theoretical approaches to the adoption and sustainability of health informatics interventions. Within each chapter use cases have been described that showed how the particular theory or framework enriched the understanding of the underlying mechanisms of health IT interventions to ultimately improve care. Although we do not pretend to have comprehensively covered the whole health informatics field with our fifteen chapters of theories and frameworks (see section 2), we believe that the theories included provide a solid base which will inspire further developments as needed.

We believe that enhanced understanding of applied theories in health informatics can make a positive addition to health IT research, implementation and education.

Researchers often have a role in designing health IT and evaluating its effect. A good example is the chapter by Gude and Peek which outlines how Control Theory was used to design electronic audit and feedback interventions and to understand the mechanisms behind it through thorough theory-based evaluation. When theories and frameworks appeared to be predictive in the success (or failure) of implementation of a health IT intervention, such as shown in the chapters on technology adaption of Ammenwerth and Greenhalgh et al, it seems unethical and inefficient when implementers of health IT intervention do not use this knowledge. We also believe this book provide important educational material to teachers and students. First it gives an overview of relevant theories and frameworks in the field. Second, by the example use cases young scientists may translate the use of these theories and frameworks to other applications they will encounter in their career. Third, the teaching questions at the end of each chapter support further discussion among students and teachers to deepen the understanding of theories and their applications.

We had three specific objectives with this book, discussed in the following sections of this concluding chapter:

- To show where and how interdisciplinary theories have been applied in health informatics
- To identify theory developed specifically within health informatics
- To highlight where further work is necessary to develop theory-based approaches.

The use cases in chapter two to sixteen show a wide range of applications of interdisciplinary theories in health informatics. We summarize and reflect upon this in sections 4-6 of this chapter. Researchers and implementers are motivated to add to this set of applications, thereby broadening the knowledge on applicability of theories in a variety of contexts. Researchers are encouraged to publish results, either positive or negative, so that all can learn from these findings. In section 7 we will discuss the limited amount of theories specifically developed within health informatics illustrating the fledgling status of health informatics as a discipline. In this final chapter we also offer our own overview of theory within the overall health informatics body of knowledge and propose a research agenda to contribute to the development of the health informatics discipline.

2. How comprehensive is our theory coverage?

We organised the chapters of this book according to two of the AMIA "foundational domains" of health informatics [60]: information science and social science (see Table 1). The third foundational domain, health science, has not directly featured in this book. Yet, of course, theory abounds in the health sciences. There are theories of ethics [41] and applied theory drawn from the natural sciences [34]. We think of the fundamental theories of Western medicine such as Harvey's theory of blood circulation [13] and the germ theory of disease [1], plus more recent developments such as the inflammation theory of disease [31] and social determinants theory [61]. The nursing profession has a rich and extensive body of theory, from Florence Nightingale onwards [44]. So far, in itself, the body of health sciences theory may seem less relevant for health informatics – though we return to this in section 6. We observe that many of the theories covered in this book might be positioned at the intersection of health science with the other domains. Moreover, with theory that is interdisciplinary there are inevitably different ways that ideas can be categorized. Life does not exist in neat boxes, so it is no surprise that health informatics theory and practice has a certain "messiness" [6].

Table 1. Fifteen interdisciplinary theories grouped by AMIA foundational domain [60]

AMIA Foundational Domain	**Theories**
Information Science and Technology	General System Theory and Process Mining Shannon's Information Theory Information Value Chain Theory User-Centred Design and Activity Theory Technology Adoption Models NASSS
Social and Behavioural Science	Distributed Cognition Actor-Network Theory Collective Mindfulness Boosting Framework Deterioration Communication Management Theory Resilient Health Care Health Behaviour Theory[1] Control Theory Normalisation Process Theory

We know that there are important topics that we have not been able to include in this volume, some simply because we could not find authors able to write within the given deadline. For example, in the Information Science and Technology section we have not covered theory related to biomedical ontologies [48], clinical information modelling [33] and healthcare information governance [38]. These would all be valuable to add in a future edition. There may also be relevant theories from computer science and statistics, especially relating to machine learning and data science more generally, that are potential candidates for inclusion. The section on Social and Behavioural Science would benefit from extensions on among others: shared mental models [57], decision theory [23], process and knowledge theory [24], practice theory [22] and team chemistry [62]. We hope this book will have regular revisions in the coming years thereby evolving the theory-base.

We invite readers to inform us about important missing applied theories in health informatics that we might include in a revised edition. Together we are responsible to mature our discipline and we believe that a theory-base is essential in this transformation.

3. Why it is important to consider theory?

"Reliance on theory demonstrates a level of sophistication in any discipline…" [11].

As in many other health care disciplines, informal theory plays an implicit role in how health informatics practitioners undertake their work. According to Davidoff et al.,

[1] This is a group of theories, not a single theory.

in their paper on "demystifying theory" the challenge is not whether theory is used, but whether the use of theory is explicated [21].

The use of theory in health informatics can help to understand phenomena, guide our analyses and improve our appreciation of the significance of research findings. Traditionally, theory has not played a dominant role in health informatics. Many researchers have noted the under-utilisation of theory to explain changes or help to predict outcomes [16]. This paucity of theory usually coincides with the absence of information about why an IT system may be useful in one context but not another [32].

Nevertheless, as this text book attests, there has been a significant uptake and growth of theory-driven approaches in health informatics particularly as a means of helping to identify concepts that are critical to understanding complex situations [11]. These developments reflect a strong push by health care administrators, software vendors, consumers, clinicians and academics to enhance understanding the outcomes of health IT systems, as a means of improving their design, implementation and sustainability into the future.

How is theory used in health informatics? It is now widely recognised that the implementation of health information systems can have a major impact on the delivery of health care and the outcomes of that care [2]. As a consequence, there is considerable attention provided to the imperative to ensure that health IT is rigorously evaluated. The utilisation of theory in health informatics has paralleled many of the developments in evaluation research over the last few decades. This is because theory can provide a frame of reference that can help us to understand the significance of evaluation findings [15]. In this way health informatics is able to go beyond a simple "black box" evaluation which may tell us whether or not a health IT system works, towards a greater appreciation of the underlying causal mechanisms and context in which it is placed.

This textbook did not intend to identify all the relevant theories currently used in health informatics. To our knowledge, there are not many comprehensive examinations of the breadth of the use of theory in health informatics [51]. This textbook provides a wide sample of theories currently employed within the health informatics discipline. Our choice of theories was purposive and informed by an intensive and iterative engagement with our health informatics colleagues over many years, including through discussions at workshops and panels at major health informatics events. Health informatics research draws from many other theories in other fields and disciplines including, sociology, psychology, information systems, implementation science and communication. Table 2 identifies some of the key disciplinary origins (drawing on Greenhalgh et al's meta-narrative on electronic patient record research [28]) of the theories presented in this textbook along with their scope and existing areas of utilisation.

Table 2. The origins, scope and utilisation of the interdisciplinary theories in this textbook.

Theory	Utilisation	Disciplinary origins	Scope
General System Theory and Process Mining	Learning health systems; Process mining of care pathways and simulation.	Complexity theory; computer science	The use of big data analytics to develop better, integrated and personalised pathways of care for patients.
Shannon's Information Theory	Assisting choice of diagnostic tests in a clinical setting; identification of redundancies in clinical tests.	Computer science; software engineering; molecular biology; statistical inference; natural language processing.	Informing medical decision making.
Information Value Chain Theory	System design; national summary EHRs; audit and feedback;	Business studies; psychology; computer science; management.	How organisations adopt and assimilate information systems.
User Centred Design and Activity Theory	Design of a mobile health IT system to improve healthcare delivery; Evaluation of a mHealth system used by community health workers.	Sociology; psychology; ergonomics; computer science; anthropology; Software engineering	Complexities of users and their interaction with computer systems.
Technology Acceptance Models	Usefulness and ease of use of EHRs among nurses; home telehealth acceptance among older people.	Evidence-based medicine; Computer science.	The benefits of digital health and how to achieve them.
Distributed Cognition	Situational awareness in cardiac surgery; Handovers in psychiatric emergency; infection control information; safety; pharmacy.	Organisational sociology; social psychology, philosophy	How social structures recursively shape and are shaped by human agency and the role of technology.
Actor-Network Theory	Medical records; IT system failures; NPfIT implementation;	Philosophy, sociology, linguistics.	Study of socio-technical networks and what emerges from these.
Collective Mindfulness	Project risk management; Adaptation of digital health systems.	Management, sociology, social psychology, anthropology.	How organisational members make sense of information systems and assimilate them.
Boosting Framework	Design of patient decision aids. Communication of risk.	Sociology; philosophy; social psychology; management.	Application of boosting theory to foster choices and shared decision making.
Deterioration Communication Management Theory	Information transfer; ICT evaluation; Junior doctor training; Care for deteriorationg patients.	Management, sociology, social psychology, anthropology.	How organisational members make sense of information systems and assimilate them.

Theory	Utilisation	Disciplinary origins	Scope
Resilient Health Care	Video consultation and triage service; Hospital response to an unexpected event.	Systems and management research; resilience engineering.	The way that systems cope successfully with unwanted outcomes (or events) that are unexpected.
Health Behaviour Theory	Smoking cessation; Choice of breast cancer therapy; Exercise.	Evidence-based medicine; social psychology; management	How to achieve organisational level change in health care.
Control Theory	Audit and feedback interventions; diabetes management; behaviour change techniques; blood transfusion practice; pain management in intensive care.	Computer science; psychology; business studies.	Self-regulation and human behaviour; why interventions were or were not successful.
Normalization Process Theory	Evaluation of a digital health intervention for Type 2 diabetes; Preoperative information system within a surgical pre-assessment clinic.	Social psychology; management	Why are new technologies and working practices implemented successfully in some settings but not in others?
NASSS Framework	Telehealth system for heart failure.	Evidence-based medicine; sociology; management; social psychology; systems and management research	The multiple influences on a complex project; how complexity might be reduced and how individuals and organisations might be supported to handle complexities.

4. What makes up a good theory and which theory should be used?

Different disciplines tend to have their own perspective of what constitutes a theory and the criteria for a good-quality theory [21]. Whilst there are some criteria that are likely to be universal (e.g., clarity of concepts, causality, testability, generalisability etc.), there are also likely to be other criteria specific to the needs of health informatics. We expect that a better appreciation of what exists in terms of theory will help to spark more attention to what constitutes a good health informatics theory. Evidence from related disciplines (e.g., implementation science, quality improvement) who face some parallel challenges to health informatics, suggest that the choice of theory is often made on an arbitrary basis, and usually based on expediency or previous exposure [7]. Clearly, this question merits attention in a research agenda for theory in health informatics.

There are different approaches to how theory is developed and tested. For instance "adaptive" theory can be defined as a combination of pre-existing theory and incoming evidence [35; 36]. Adaptive theory approaches can thus be shaped by research evidence, even while the pre-existing theoretical material (framework, concept) is helping to shape the course of evidence gathering. Alternatively, "grounded theory" is based on the notion that theory emerges from the research data. For grounded theory [26; 36] one of the measures for judging the relevance of a theory is whether or not it is comprehensible to the subjects of the research.

5. Limitations

In addition to the limitations of scope discussed in section 2, it is helpful also to reflect on the explicit limitations of each theory. Table 3 summarises the limitations identified in each chapter by the authors.

Table 3. Explicit limitations of the interdisciplinary theories in this textbook.

Theory	Limitations
General System Theory and Process Mining	"Anything could be seen as a system depending on the boundaries you set".
Shannon's Information Theory	Need to explicitly model the "noise" that is inherent in the communication model. Shannon entropy, relative entropy and conditional entropy are non-intuitive concepts.
Information Value Chain Theory	Relatively new, with few applications. The theory does not attempt to provide detailed mechanistic explanations for the impact of information technology beyond the causality implied in the structure of the chain itself. As with any theory that relies on quantitative measurements, it is important to ensure that data used in any analysis actually measures what it is meant to.
User Centred Design and Activity Theory	Software application needs to collect and infer relevant contexts to understand the user's situation. Users will invariably have different perceptions, understanding and expectations, influenced by social, cultural and historical context.

Theory	**Limitations**
Technology Acceptance Models	A number of TAM extensions have been proposed to overcome some limitations in the original model.
Distributed Cognition (DiCoT)	Distributed cognition encourages a level of description about a system or process that lends itself to developing design ideas, but it may not readily emphasise the role of individuals or emotions as it focuses on systems and more observable functional issues.
Actor-Network theory	Lack of predictive power. Not internally consistent. Lacks specificity. Treatment of human actors and non-human actors as equal. Terminology is only loosely defined.
Collective Mindfulness	Rarely applied in health informatics. Recommendations may be difficult to put into practice. Principles could be viewed as ideals rather than descriptors.
Boosting Framework	Rarely applied in health informatics. It is a framework not theory and it helps to explicate some guiding principles for future research, from which testable assumptions can be derived. The boosting framework does not yet provide a full-blown process model with detailed "how-to" information describing how research evidence can be translated into practical health informatics solutions.
Deterioration Communication Management Theory	Classical Grounded Theory (CGT) focuses on one main concern, unlike constructivist Grounded Theory (GT) which aims to understand multiple perspectives in a social process. CGT has seldom been used in information systems research.
Resilient Health Care (RHC)	Resilient Health Care theory is relatively new and many of its tools are still in their infancy. RHC tools may be used to complement determinant frameworks such as computational simulation modelling.
Health Behaviour Theory	The use of behaviour change theory in health informatics interventions originates mainly from other disciplines: psychologists and public health workers familiar with behaviour change theory. Many interventions developed by people working in health informatics do not report using a health behaviour or behaviour change theory.
Control Theory (CT)	In the Audit & Feedback literature it has often been used but not explicitly reported. HI interventions are typically complex and placed into a social and organisational context. This context is not in the scope of CT. It provides no guidance as to which factors related to the context, recipients, or feedback itself may influence success of the feedback loop.
NASSS Framework	Published studies about the application of the NASSS framework are limited. Key challenge is to find ways of "running with" complexity, instead of seeking to "eliminate it".

6. Does health informatics have any theory of its own?

So far, we have focused on the first of our three objectives: to show where and how interdisciplinary theories have been *applied* in health informatics. Most of the theories have been *developed* in other fields. We now turn to the question of theory developed specifically within health informatics, to consider where further work is necessary to develop theory-based approaches.

We suggest that there are only three examples of "native" health informatics theory in the textbook:

- Distributed Cognition (as it is specifically about "information processing in sociotechnical systems")
- Deterioration Communication Management Theory (as its aim is "to improve the design and implementation of ICT systems for communication to and from junior hospital doctors")
- The NASSS Framework (as it is focused explicitly on "technologies in health and care organizations").

What else is out there?

Arguably, the oldest theories in health informatics are the "determinant frameworks" (in Nilsen's terminology [45]) relating to the structure and content of patient records. This is unsurprising as it is perhaps the most obvious overlap between healthcare and information. In 1605, Francis Bacon harked back to the narrative case histories of the school of Hippocrates as the ideal [20]. Later, Thomas Sydenham, the 'English Hippocrates', wrote in 1676 that an "exact history" of every case of disease would improve therapy by making it empirically obvious how to proceed [20]. Francis Clifton proposed to the Royal Society in 1731 that medical observations should be recorded in a particular tabular format to simplify record-keeping and facilitate comparative analysis [50]. In the 1960s, Larry Weed famously proposed problem-oriented medical records "to guide and teach" [63; 64] and this approach has been adopted in some electronic health record systems. Recent health informatics work has included the development of detailed clinical information models of re-usable concepts in representations such as archetypes [43] and Fast Healthcare Interoperability Resources (FHIR) [58]. While that modelling work is for the purpose of technical implementation not informatics theory, there is still an implied hypothesis that such shared concepts are sufficiently stable, definable and comprehensible to be safe and meaningful as a common language of healthcare.

The most basic theory in modern health informatics seems to be Friedman's fundamental theorem [25]. Friedman asserted that "A person working in partnership with an information resource is 'better' than that same person unassisted", with three important corollaries: (1) That informatics is more about people than technology; (2) In order for the theorem to hold, the resource must offer something that the person does not already know; and (3) Whether the theorem holds depends on an interaction between person and resource, the results of which cannot be predicted in advance. The theorem has been questioned [40] and modifications to the wording have been suggested [30; 39], but the common sense of Friedman's theorem seems generally accepted.

Another quite basic proposition is the "first law" that van der Lei proposed: "data shall be used only for the purpose for which they were collected". The continuing validity of this has been questioned [54] and it is expressed as a normative principle rather than an explanatory model or predictive hypothesis, but there is an implicit prediction that if the “law” is not followed then the conclusions from the data will be flawed.

We have not conducted a systematic review, but in the preparation of this textbook we have informally reviewed a broad range of literature and in Table 4 we offer an illustrative sample of contributions that might be regarded as theory in health informatics.

Table 4. A sample of candidate theories in health informatics.

Reference	What is the “theory”?	What does it claim to explain?
[3]	Thematic Hierarchical Network Model for Computerised Physician Order Entry (CPOE) Consequences.	Relationship between categories of unintended consequences of CPOE.
[4]	Sociological perspective on EHR design.	That medical work is not a linear rational process, so EHR design should rather support fluidity of knowledge and collaborative, interactive working.
[5]	Human Factors Engineering (HFE) approach to biomedical informatics applications for healthcare.	That HFE shows why implementations are successful or not.
[8; 9]	Cognitive span of the process of clinical diagnosis.	That it is at the latter end of the diagnostic process that decisions become algorithmic and therefore when computers become potentially useful.
[12]	Clinical domain reference ontologies.	The ideal features and attributes of reference ontologies for a specific clinical knowledge domain.
[17]	Thematic synthesis of controlled medical vocabulary requirements.	The ideal features and attributes of a computable controlled medical vocabulary.
[18]	Alternative paradigm for modelling clinical interactions based on psychological concept of “common ground”.	That the typical computational model of communication does not correspond with actual clinical experience of mostly interrupt-driven human interaction.
[46]	Three general principles to determine whether CPOE implementation will succeed.	Why CPOE implementations succeed or not.
[47]	A nine-factor construct of clinician perceptions about computerized protocols.	How clinicians react to computerized protocols.
[49]	Evaluation model of clinical information systems viewed from health system perspective rather than functional or organizational assessment.	That the full picture of time effects of clinical systems can only be evaluated at whole-system level not just by unit component effects.
[55; 56]	Architecture for sharing EHRs independently of disparate healthcare providers.	That independent health record banks offer a more sustainable solution for lifetime EHRs than records held by providers, payers or government agencies.

As noted in section 3, the development or application of theory in health informatics is predominantly implicit rather than explicit. Readers (and editors of theory textbooks!) are usually left to infer the theoretical contribution. The STARE-HI guideline for reporting of evaluation studies in health informatics [10] includes "theoretical background" as a section in Methods – this is very far from routinely followed. We certainly would not want to see our field adopt an extreme position where theory is idolized and academic papers become weighed down with ponderous and pretentious intellectual displays, as has been reported in the field of management [29], but health informatics generally appears to be at the opposite end of that spectrum and needs a nudge towards a stronger theoretical approach.

7. A research agenda for theoretical health informatics

Finally, we consider theoretical topics for future research that have been identified in the literature and some that we propose based on our learning in preparing this textbook.

From Table 4, we offer some specific areas for consideration:

- Theory of CPOE implementation
- Theory of sociological design of EHRs
- Theory of computational diagnostic support
- Theory of clinical communication patterns
- Theory of healthcare protocol adoption
- Theory of systemic evaluation
- Theory of personally controlled electronic health records.

The converging paradigms of precision medicine, Learning Health Systems and implementation science seem to offer a particularly fruitful ground for theory development given the central role of informatics in each of these fields [14; 52; 59]. A key aspect of this convergence is clinical decision support, which has long been an important area of study in health informatics [27; 42], though the robustness of its evaluation still has a way to go in terms of scientific measurement practice [53]. The need for sound theoretical foundations for this work has been recognised [23; 24] but in some quarters seems to be perceived as merely a technical implementation challenge. We argue that this is a prime area where we should expect to see emerging theory.

In addition to these specific topics, there is the general lack of replication studies in health informatics [19]. Without such a culture of replication studies, our field will be dominated by single-case evaluations that do not lend themselves to broader theoretical generalisation. Theories may not lend themselves to the same form of replication of findings but there is still a need for validation. Theoretical approaches often take a triangulation approach or utilise member validation methods.

We have already noted in section 4 that criteria need to be developed for selecting relevant theory and assessing theory quality. As suggested in [7], there should be transparent reporting of the criteria used to select theories in research studies. This implies the need for a comprehensive list of criteria that are used to choose a theory. Such an approach in health informatics would encourage reflective thinking, explication and generalisability. The theory criteria would include the identification of key constructs; informing data collection; enhancing conceptual clarity; clarifying terminology and hypothesising relationships [7]. This would be a useful contribution to the field and could inform the revision of existing reporting guidelines [10].

8. Conclusion

We thank our readers for joining us on this journey into the theoretical side of health informatics. We have learned much and enjoyed developing the book. We hope you find the book useful and welcome suggestions for a more extensive second edition. Finally, we hope that you are now part of the health informatics community that agrees with Lewin that: “there is nothing more practical than a good theory” [37].

Teaching questions for reflection

1. In your area of health informatics practice, what would you identify as the most useful interdisciplinary theories in this textbook?
2. What additional theories can you propose for a future edition of the textbook?
3. How would you evaluate the scientific maturity of health informatics, based on its current approach to theory?
4. What do you feel are the priorities for theoretical topics in health informatics that need further research?
5. What would criteria for health informatics theory selection look like?

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